Telecommunication Standards Development

The Institute contributes significantly to the development and application of national and international telecommunications standards. These standards provide a technological framework for evolving U.S. and global information infrastructures, promote innovation and competition in telecommunications products and services, and enhance international trade opportunities for U.S. telecommunications firms. Institute staff members provide leadership and technical contributions to key national and international standards committees including the American National Standards Institute-accredited Committee T1, the Telecommunications Industry Association, the Federal Telecommunications Standards Committee (FTSC), the International Telecommunication Union's Telecommunication Standardization and Radiocommunication Sectors (ITU-T and ITU-R), and others. The technical standards and recommendations developed in these fora are blueprints for technology evolution and can influence billions of dollars in telecommunications research and development investments worldwide.

Areas of Emphasis

ITU-T Standardization Activities

The Institute leads U.S. ITU-T committees and work groups, prepares technical contributions to advance ITU-T standards development, and drafts proposed ITU-T recommendations and compatible national standards. Projects are funded by NTIA.

Video Quality Standards Development

The Institute contributes to the development of standards defining perception-based, technology-independent video quality measures. Projects are funded by NTIA and by the National Communications System (NCS).

Audio Quality Standards Development

The Institute contributes to the development of standards that specify technology-independent measures of audio quality as perceived by human listeners. Projects are funded by NTIA and NCS.

Broadband Networks

The Institute contributes to the development and deployment of broadband integrated services digital network/asynchronous transfer mode (B-ISDN/ATM) technologies through network performance measurement studies and standardization activities. Projects are funded by NTIA and NCS.

Telecommunication Terminology Standards

The Institute leads and contributes to the development of telecommunications terminology standards in Federal, national, and international fora. Projects are funded by NCS.

Wireless Standards Support

The Institute contributes to the development of industry standards for personal communications services and wireless local area networks and provides objective testing and evaluation of the associated technologies. Projects are funded by NTIA and U.S. West Advanced Technologies.

Standards for Radiocommunication Systems

The Institute provides leadership and technical support to the FTSC in developing interoperability and performance standards for HF and land mobile radio systems. Projects are funded by NCS.

ITU-T Standardization Activities

Outputs

- U.S. and international ITU-T leadership.
- Technical standards contributions.
- Proposed ITU-T recommendations.

The International Telecommunication Union-Telecommunication Standardization Sector (ITU-T) plays a preeminent role in the cooperative planning of public telecommunications systems and services worldwide. The technical standards (recommendations) developed in the ITU-T have substantial impact on both the evolution of the U.S. telecommunications infrastructure and the competitiveness of U.S. telecommunications products and services in international trade. The Institute supports ITU-T activities by leading U.S. preparatory committees and international work groups, preparing technical contributions to ITU-T standardization activities, and drafting proposed recommendations of particular importance to U.S. Government and industry.

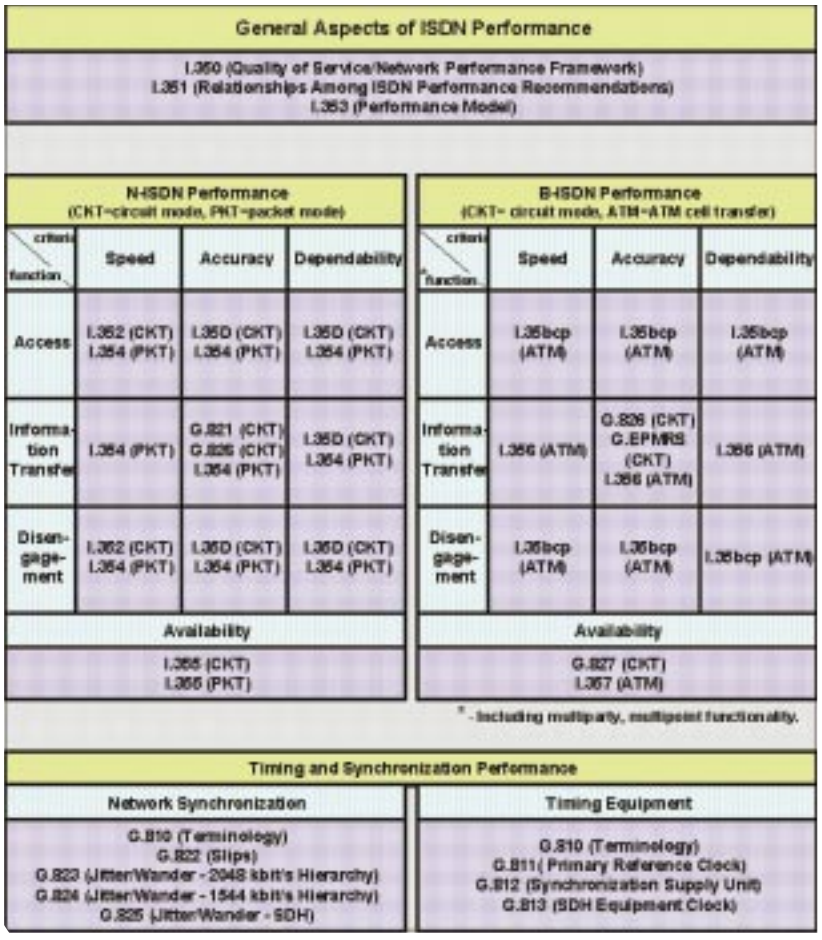
The Institute provides strong support to the U.S. Department of State in leading the U.S. Organization for the ITU-T. Institute personnel serve on the U.S. International Telecommunications Advisory Committee (ITAC), provide technical leadership and administration for U.S. ITU-T Study Group B, and head the U.S. Delegations to international meetings of ITU-T Study Group 13. The U.S. ITAC guides overall U.S. participation in ITU-T activities. U.S. Study Group B approves and presents U.S. contributions to ITU-T Study Groups 9 (Television and Sound Transmission), 10 (Languages for Telecommunication Applications), 11 (Switching and Signaling), and 13 (General Network Aspects). Study Group 13 develops recommendations for advanced broadband networks using high-speed synchronous digital hierarchy (SDH) and asynchronous transfer mode (ATM) systems, and is leading ITU-T efforts to define the Global Information Infrastructure (GII) envisioned by Government leaders and network planners in many countries.

During FY 96, the Institute assisted the Department of State and other U.S. ITAC members in preparing for the World Telecommunications Standardization Conference (WTSC). The WTSC approves the overall ITU-T work program for each 4-year study period, establishes the ITU-T study groups, assigns technical projects (questions) to each study group, and formally approves proposed changes in ITU-T work methods and relationships. ITS contributions to the WTSC planning process proposed innovative ways of strengthening U.S. industry participation in the ITU-T consistent with national objectives. In other U.S. ITAC work, ITS headed the U.S. Delegation to a May 1996 meeting of ITU-T Study Group 13 at which 8 revised and 13 new recommendations were approved. At this meeting, ITS participated in developing 29 new and revised questions that will guide the Study Group 13 technical program during the 1997-2000 ITU-T Study Period. Several of the proposed new questions deal with cooperative international development of the GII.

The Institute also provides strong leadership in ITU-T and American National Standards Institute (ANSI)-accredited standards committees whose work is relevant to the Department of Commerce goals. During FY 96, Institute representatives (1) provided technical leadership of ITU-T Working Party 4/13, and the ITU-T Rapporteurs Groups for Questions 13 and 22/12; (2) continued technical contributions and assumed new management responsibilities in ANSI-accredited Technical Subcommittee T1A1; and (3) provided organizational and administrative assistance to Technical Subcommittee T1S1. Working Party 4/13 develops performance specifications and measurement methods for narrowband and broadband integrated services digital networks (ISDNs). The Question 13/12 and 22/12 Rapporteurs Groups define subjective and perception-based objective quality of service measures for speech transmission and audio/visual systems. Technical Subcommittee T1A1 develops performance and signal-processing standards for emerging broadband networks and multimedia services. Technical Subcommittee T1S1 develops service, architecture, and signaling standards for North American ISDN applications. An ITS staff member assumed a new leadership role as T1A1 Information Director during FY 96. Initial work resulted in the implementation of electronic document-handling procedures that advanced the development of technical standards in the T1A1 Subcommittee.

During FY 96, the Institute's leadership and technical contributions in ITU-T Study Group 13 significantly assisted the completion of two revised ISDN performance Recommendations: I.356 and I.351. Recommendation I.356 specifies numerical performance objectives and quality of service classes for international ATM connections. The specified values will facilitate ATM network planning and will assist users in selecting ATM network services to meet their broadband communication needs. Recommendation I.351 defines the overall framework for a set of related recommendations that collectively provide a comprehensive basis for the specification and apportionment of performance in narrowband and broadband ISDNs.

The Figure illustrates the overall scope of ITU-T Study Group 13 Working Party 4 performance standardization activities as summarized in Recommendation I.351. Four distinct types of performance recommendations are being developed. *General* recommendations define the performance description framework, principles, and reference models used in other recommendations. *Primary* recommendations define protocol-specific performance parameters, objectives, and measurement methods for narrowband and broadband ISDNs in the context of the ITS-developed 3x3 matrix framework. The matrix identifies three protocol-independent telecommunication functions: access, user information transfer, and disengagement. Each function is considered with respect to three general performance concerns (or "performance criteria"): speed, accuracy, and dependability. Recommendations within a particular cell define one or more "primary parameters" that characterize performance relative to that particular function/criterion pair. *Availability* recommendations distinguish service outages from intervening periods of acceptable performance (by comparing observed primary parameter values with corresponding outage thresholds) and establish limits on the frequency and duration of outage periods. *Timing and synchronization* recommendations specify accuracy and precision objectives for network time and frequency reference sources and distribution systems.



Relationships among ISDN performance recommendations.

During FY 96, Institute staff members also spearheaded technical work on a key domestic B-ISDN performance standard, ANSI T1.511. This revised standard will specify and allocate cell transfer performance objectives for national ATM services. It is being developed as a "delta" document that will reference the performance parameter definitions and objectives specified in ITU-T Recommendation I.356. This approach will maximize compatibility among national and international performance standards—a key objective of ITS participation in ITU-T standardization activities.

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Video Quality Standards Development

Outputs

- Contributions to national and international video quality measurement standards.
- Automated video quality measurement techniques and prototype instrumentation.
- Technical input to development of U.S. policies on advanced video technologies.

Digital compression and transmission techniques offer an economical means of implementing video communication services in emerging national and global information infrastructures. However, the quality of digital video systems cannot be evaluated using the static test patterns and waveform reproduction measures traditionally used in assessing analog video systems. ITS engineers are addressing this problem through the development and standardization of a fundamentally new methodology for video quality assessment. The ITS-developed methodology employs natural video scenes (rather than artificial test patterns) as input material, and captures the observable effects of a wide range of impairments using *perception-based* video quality parameters. These parameters have been selected for their correlation with the subjective assessments of human viewer panels. The ITS-developed parameters are specified in American National Standards Institute (ANSI) T1.801.03-1996 ("American National Standard for Telecommunications - Digital Transport of One-Way Video Signals - Parameters for Objective Performance Assessment"), published in February 1996. These parameters can be used to characterize both spatial and temporal distortions in the output video.

Figure 1 illustrates the use of one objective parameter that was developed at ITS and included in ANSI T1.801.03-1996. This parameter measures the perceptual effects of error blocks. Error blocks are a form of distortion in which one or more blocks (groups of pixels) in the output image bear no resemblance to their counterparts in the current or previous scene. Error blocks often are caused by transmission errors in compression systems that use the discrete cosine transform (DCT). DCT-based compression systems are specified, for example, in Motion Picture Expert's Group (MPEG) standards and in International Telecommunication Union-Telecommunication Standardization Sector (ITU-T) video-conferencing recommendations (e.g., H.261/H.263). The ITS-developed measure calculates temporal gradients for each image pixel by subtracting, pixel by pixel, *frame n-1* (one frame earlier in time) from *frame n*. The right-hand image in Figure 1 shows the absolute magnitude of the temporal gradients for two successive frames; the larger temporal gradients (white areas) are due to the sudden appearance of error blocks. The temporal information (*TI*) feature is computed from the temporal gradient image by summing all the energy, or white areas. *TI* thus quantifies the total motion that is present at each video frame. The sudden appearance of the error blocks produces a relatively large amount of added *TI*. The graph in Figure 1 shows how the appearance and disappearance of an error block causes spikes, or sudden increases, in the *TI* values. The perceptibility of these error blocks is related to the logarithmic ratio of the output to the input *TI* values. Thus, error blocks are more noticeable in low-motion scenes.

During FY 96, ITS engineers demonstrated the effectiveness of temporal and spatial gradients in analyzing the quality of a video data set that included 10 MPEG systems (operating from 1.5-8.3 Mb/sec) and 8 analog broadcast systems with different quality levels. The analysis of this data set was completed as part of a cooperative research and development agreement with a large U.S. video service provider. A panel of viewers was used to subjectively rate the mean opinion score (MOS) of the video on a quality scale from 1 (very annoying impairment) to 5 (imperceptible impairment). Figure 2 shows the results from two different predictive models plotted against the MOS of the viewer panel. Figure 2(a) used ITS-developed objective metrics from temporal and spatial gradients; Figure 2(b) used the traditional peak signal-to-noise ratio (PSNR) metric (obtained by subtracting the output image from the input image and summing the resultant error). The model, based on gradients, explains about 80% of the subjective information, while the model based on PSNR explains only 20% of the subjective information.

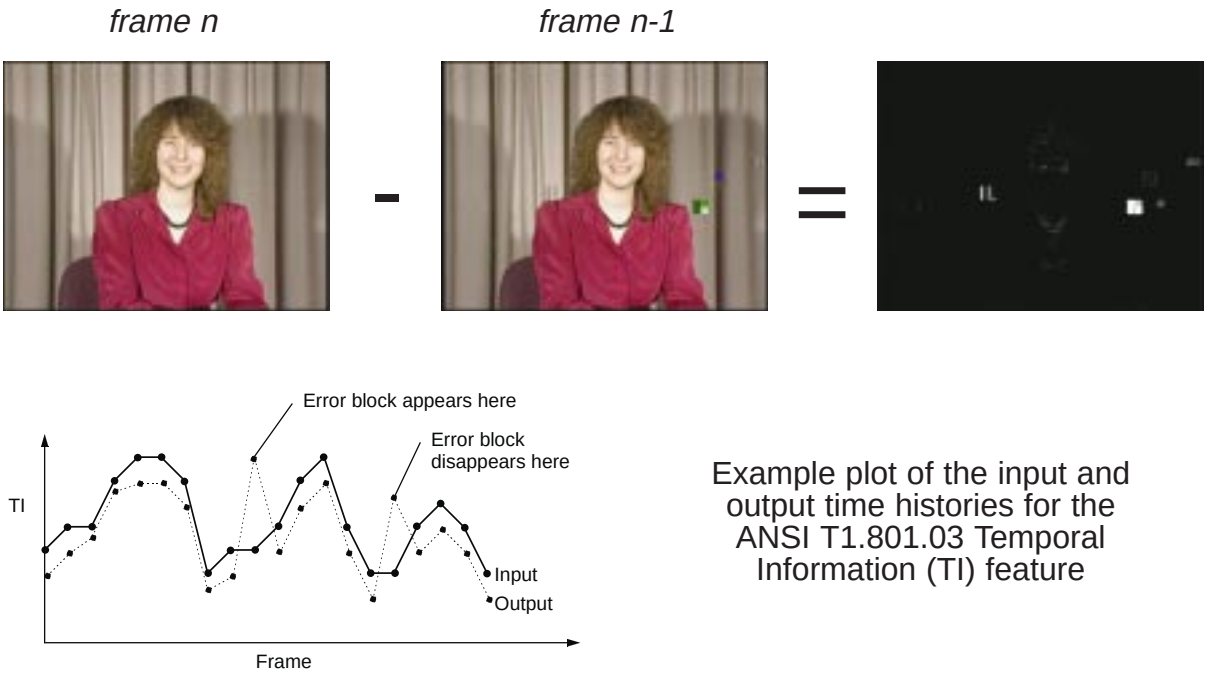

Figure 1. Objectively measuring the perceptual effects of error blocks.

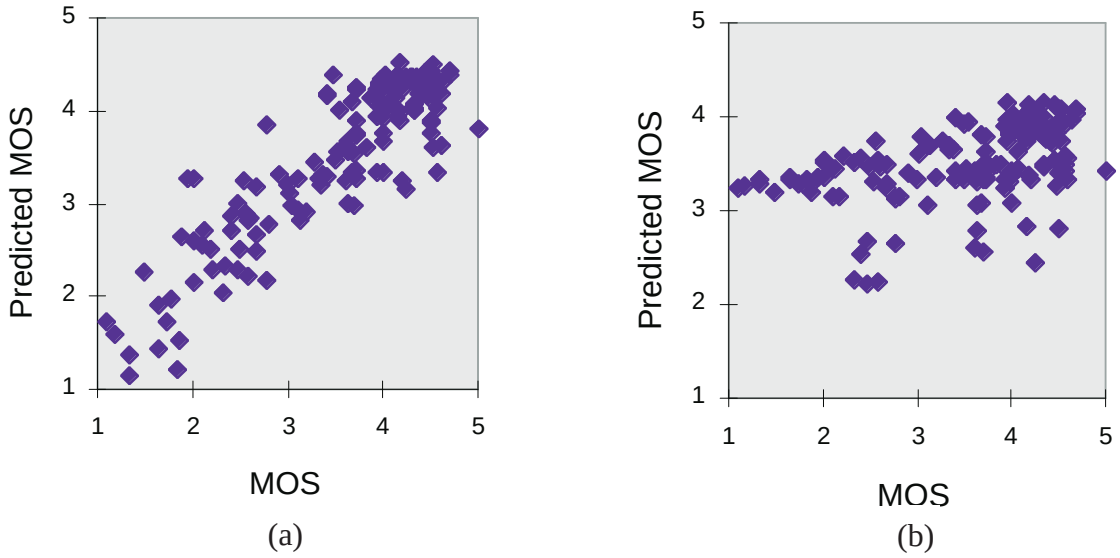

Figure 2. Model predictions for an MPEG data set: (a) = model using spatial and temporal gradients and (b) = model using PSNR.

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Audio Quality Standards Development

Outputs

- Objective audio quality assessment algorithms.
- Prototype audio quality test instruments.
- Contributions to standards organizations.

With technologies for digital audio encoding, compression, and transmission becoming more and more diverse, there is a growing need for objective audio quality measures that correlate well with human perception. Existing and proposed systems for transmitting audio signals over digital networks now include 4-kHz speech systems, with bit rates ranging from 1.2-64 kbit/s; 7-kHz speech systems, with bit rates from 16-64 kbit/s; and 15- to 20-kHz multichannel audio systems, with bit rates from 64-128 kbit/s per channel.

Many digital systems represent audio signals by encoding their frequency content or other characteristics rather than by simple waveform representation. The encoded bit streams may be carried by radio, wire, or optical fiber transmission systems and may be multiplexed with video and data streams in multimedia communications. Increasingly, digitized audio signals are being transported in asynchronous transfer mode (ATM) cells, which can be subject to variable delay and other impairments not previously observed. The interactions among audio signal content, source coding, channel coding, and channel conditions are complex and system-dependent. Not surprisingly, traditional waveform reproduction measures developed for wired 4-kHz analog telephony often are ineffective in assessing the listener-perceived quality of digital audio systems.

The most fundamental and accurate measures of audio quality are the subjective responses of users. These responses can be obtained formally by conducting subjective listening tests. However, in many situations the time and expense required by these precisely controlled tests are not justified. In its Audio Quality Standards Development program, the Institute addresses these situations by developing practical alternatives to subjective listening tests: digital signal-processing algorithms that objectively estimate perceived audio quality in ways that correlate well with subjective listener judgments. The development of these objective audio quality assessment algorithms parallels subjective testing operations. Objective estimates of perceived audio quality are compared with the corresponding subjective test results to ensure that truly useful algorithms are developed.

During FY 96, ITS staff designed and constructed a subjective testing facility to support this work (Figures 1 and 2). The subjective tests are conducted in an acoustically isolated and treated room that conforms with international recommendations for subjective listening and viewing tests. Before a test begins, the test subject is given a basic hearing screening to ensure that his or her hearing characteristics do not deviate too far from average hearing characteristics. Test participants hear test materials through headphones or loudspeakers and use an electronic pen to record their responses on a small screen. This system allows a participant to proceed through a test at a comfortable pace, and eliminates the need for manual data entry after a test is completed. Workstations equipped with 16-bit digital-to-analog converters control the reproduction of test material and the collection of responses. FY 96 activities included a substantial initial test in the new subjective testing facility: 24 participants each responded to 200 recordings, taken from 50 different audio systems.

The ITS approach to the development of objective audio quality assessment algorithms is *perception based*. The basic premise of the perception-based approach is that by transforming audio signals into an appropriate perceptual domain, only information that is perceptually relevant is retained. By definition, that information is both necessary and sufficient for the accurate assessment of audio quality, independent of the coding, transmission, and decoding applied to the audio signals. In seeking appropriate perceptual transformations, ITS staff members study the modeling of human hearing processes as well as higher-level processes of perception and discrimination. Key elements of the human hearing processes are frequency-dependent sensitivity, limited frequency resolution, limited temporal resolution, and amplitude transfer characteristics. In general, these processes are neither linear nor time-invariant.

Figure 1. ITS staff member using the audio control station for the ITS subjective testing facility (photograph by D.J. Atkinson).

Once audio signals have been transformed into the perceptual domain, they must be compared in a way that mimics human judgement. While much is known about human hearing, relatively little is known about human judgement of sounds. Subjective tests provide the empirical data that allow the development of useful comparison algorithms. ITS staff have developed a novel comparison technique that is based on a sequence of time- and frequency-domain normalizations, conducted over decreasing time and frequency scales.

One important objective of the Institute's Audio Quality program is to advance the development of audio performance standards in the American National Standards Institute (ANSI)-accredited Standards Working Group T1A1.7 (Signal Processing and Network Performance for Voiceband Services). Institute staff members presented technical contributions summarizing recent research findings at T1A1.7 meetings during FY 96. The Institute

Figure 2. Test participant listens to audio recordings and responds using an electronic pen and screen (photograph by D.J. Atkinson).

also contributed to related performance studies in International Telecommunication Union-Telecommunication Standardization Sector (ITU-T) Study Group 12. An Institute staff member serves as Associate Rapporteur on Question 13/12, which addresses methods of modeling and measuring nonlinear distortion processes in voice transmission. Relevant results also were presented in the Federal Telecommunications Standards Committee's Multimedia Telecommunication Performance Measurements Subcommittee, which is led by ITS.

The Institute's results on objective audio quality have been disseminated widely through technical publications and presentations at meetings and workshops involving industry, Government, and academia. During FY 96, staff members demonstrated ITS-developed prototype audio quality test instruments to industry and Government visitors and to attendees at technical standards meetings. The prototype instruments consist of personal computers with 16-bit analog-to-digital and digital-to-analog converters. Custom software implements objective measures of audio quality in real time, enabling researchers to identify more quickly the most practical and useful measures. These prototype instruments have generated significant industry interest and are expected to lead to the development of commercial products that implement the Institute's objective audio quality assessment algorithms.

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Broadband Networks

Outputs

- B-ISDN/ATM emulation and measurement capabilities and results.
- Multimedia performance measurement capabilities and results.
- Standard performance parameters and measurement methods.

Emerging broadband integrated services digital network (B-ISDN) and asynchronous transfer mode (ATM) technologies offer unprecedented transmission capacity and channel assignment flexibility to network designers. They are expected to play a key role in realization of the "information superhighways" envisioned by industry and Government planners worldwide. However, these technologies have transmission performance characteristics fundamentally different from those observed in traditional isochronous networks, and require complex traffic control and resource management mechanisms that are not yet fully defined. The Institute's Broadband Networks program contributes to the development and successful deployment of B-ISDN/ATM technologies through network performance measurement studies and associated standardization activities. During FY 96, ITS staff members developed a laboratory infrastructure for multimedia performance experiments, investigated the relationship between physical-layer, ATM-layer, and application-layer performance with B-ISDN/ATM test equipment, and published an NTIA Report summarizing these investigations (see Recent Publications, below).

As multimedia and other National Information Infrastructure (NII) applications evolve, it will become increasingly important for providers and users to understand the relationships among performance values observed at different network protocol layers. During FY 96, ITS personnel used the video and broadband network portions of the laboratory infrastructure illustrated in Figure 1 to investigate the relationships among physical-layer, ATM-layer, and application-layer performance for two types of video

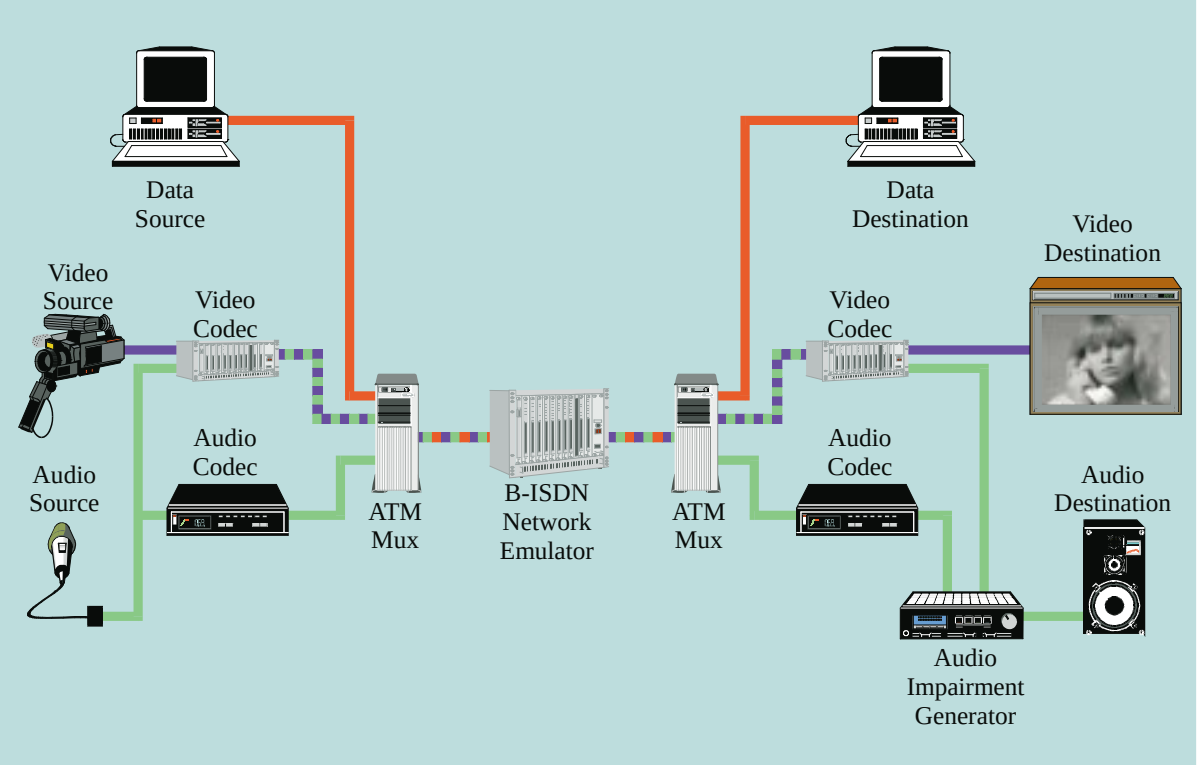

Figure 1. Infrastructure for multimedia performance experiments.

signals: differential pulse code modulated (DPCM) video at 45 Mb/s and International Telecommunication Union-Telecommunication Standardization Sector (ITU-T) Recommendation H.261 video at 384 kb/s and 1.536 Mb/s. Experiment results indicated that small variations (less than 10%) in physical-layer performance can cause much larger variations (greater than an order of magnitude) in the higher-layer performance parameters. These results were influenced by several factors, including the types of physical-layer impairments introduced, the types of error control used, and the performance parameter definitions. The first two factors were varied in the experiments.

The types and distribution of physical-layer errors were varied through modification of the parameters of the physical-layer error model. Viewed in its finite state representation, this model consists of four states: error free, low error, moderate error, and severe error, as illustrated in Figure 2. Changing the specific error levels determined by the states and the frequency of transition between the states provides the control required to implement a variety of error scenarios. For example, in the video experiment, two different types of "severe" impairments were introduced: (1) a very high bit error ratio (10^{-2}), causing a fairly high percentage of errored and lost cells over a 20-ms period; and (2) a loss of signal, causing total data loss over a 1- to 2-ms period. The effects of clustering or dispersing physical-layer errored second events in time also were examined. In one scenario, the errored seconds occurred in isolation at approximately 6-s intervals; in the other, the errored seconds occurred successively, averaging 10 consecutive errored seconds in a 60-s period.

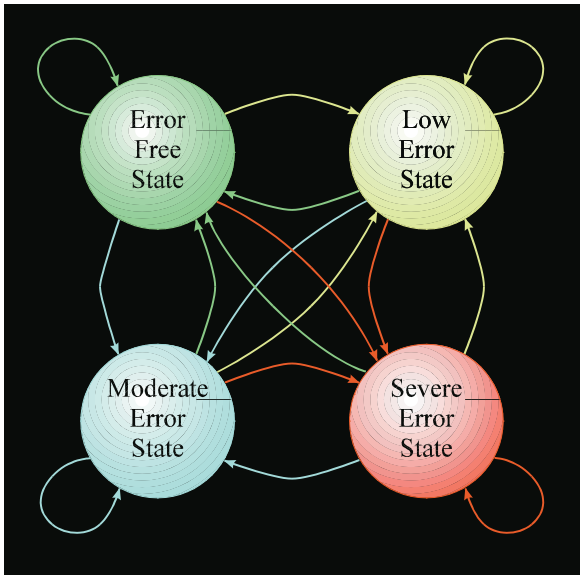

Figure 2. Physical-layer error model used in multilayer performance comparisons.

Variation in the emulated system's response to errors was achieved through selection of the video algorithms used. The DPCM video-coding equipment had virtually no error correction/detection capabilities, and an error in the bit stream was observed to cause a momentary visible flicker in the displayed video. At higher error ratios, a strobe-like effect, that viewers would subjectively classify as "annoying," was produced. The H.261 video, on the other hand, was fairly robust to error ratios up to 10^{-5}, but could take several seconds to recover when an error did appear. When errors became severe, the H.261 video occasionally "froze" as the coders/decoders lost synchronization; in these extreme cases, recovery took as long as a minute. This variability could be addressed through the development of a "vertically integrated" performance model (e.g., performance parameters that indicate the relationship between user-perceived performance and network transmission artifacts). Experiments to examine the feasibility of this approach are ongoing.

The experiments and results summarized here are described more comprehensively in an NTIA Report published during FY 96. The report also summarizes development of the ITS Broadband Network Emulator and related B-ISDN/ATM infrastructure capabilities.

Recent Publications

D.J. Atkinson, "Exploring B-ISDN performance: selected experiments and results," NTIA Report 96-329, Apr. 1996.

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Telecommunication Terminology Standards

Outputs

- U.S. contributions to ISO/IEC information technology vocabulary standards.
- Camera-ready copies of *American National Standard Dictionary for Information Technology* and *Glossary of Telecommunication Terms* (Federal Standard 1037C).
- CD-ROM and HTML/World Wide Web versions of Federal Standard 1037C.

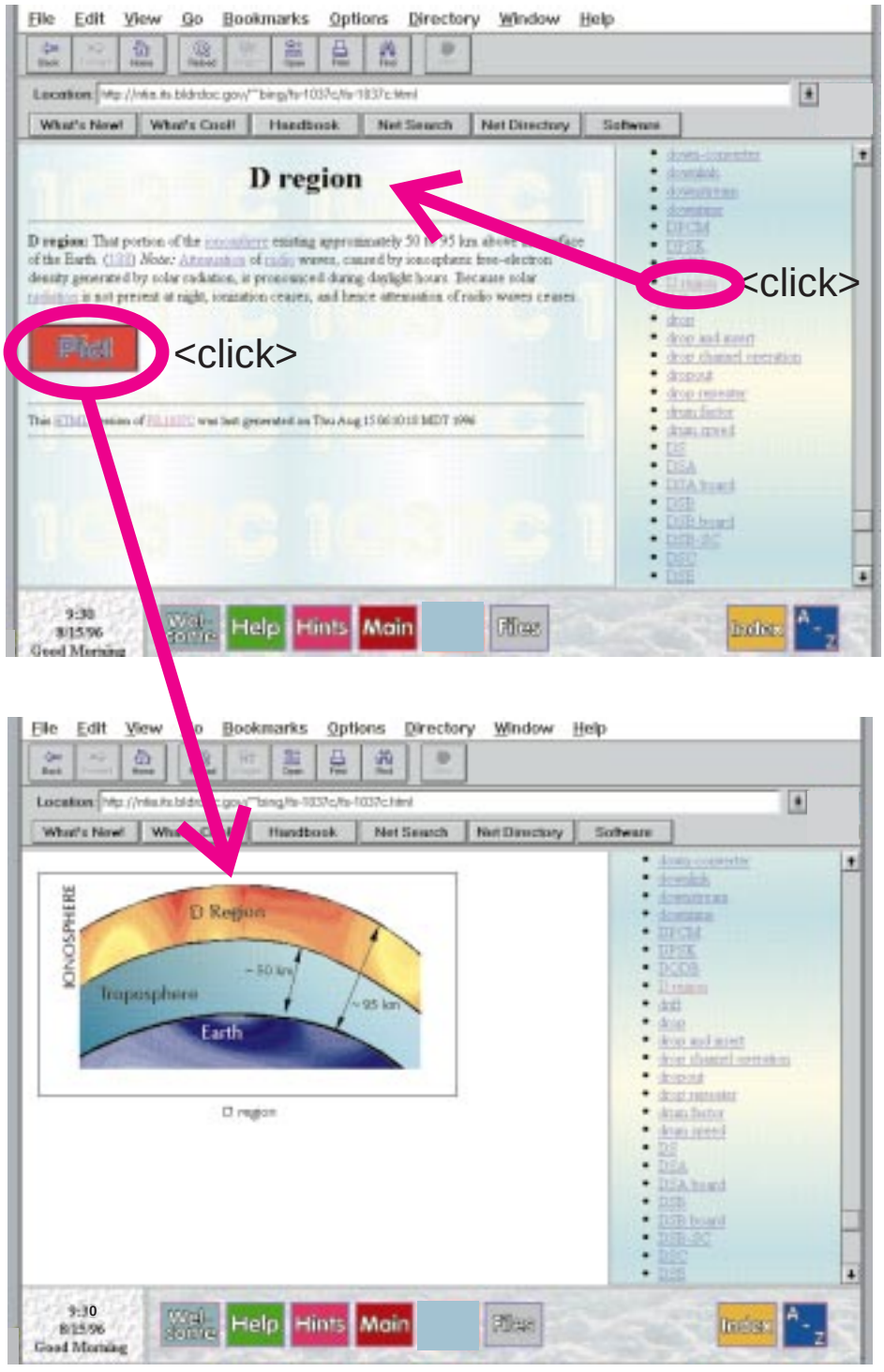
Clear communication of facts and ideas depends upon a common understanding of terminology. Such understanding is particularly important—and particularly difficult to achieve—in the rapidly growing field of telecommunications. Specification and deployment of advanced telecommunication systems depends on consistent interpretation of a specialized vocabulary that is immense, complex, and dynamic. Common understanding of telecommunication terminology also is important in ensuring the marketability of U.S. telecommunication products and services in international trade. Telecommunications and information terminology standards developed under ITS leadership contribute strongly to clarity and precision in telecommunication publications and specifications—and indirectly, to all of the aforementioned goals.

Standardized definitions of telecommunication terms are being developed in Federal, national, and international fora. ITS contributes to vocabulary standards in all three fora under the sponsorship of the National Communications System (NCS). The Institute's work in the Federal forum benefits NCS by standardizing vocabulary in—and thereby promoting advancement of—National Security Emergency Preparedness and the National Information Infrastructure. During FY 96, ITS continued its leadership of the Federal Telecommunications Standards Committee Subcommittee to Revise Federal Standard 1037B. The group completed and delivered the camera-ready copy of Federal Standard 1037C, *Glossary of Telecommunication Terms*, in September 1996. Institute staff members also developed a hypertext version of that 5800-entry glossary. More than 80 illustrations are included—many of which are in color in the hypertext version. One such illustration is shown in the Figure. The hypertext version of the Standard resides at *http://glossary.its.bldrdoc.gov/fs-1037* on the World Wide Web. The hypertext version and a compatible .PDF version are also accessible on a CD-ROM available from the NCS. The CD-ROM includes browsers to allow access to both versions of the document on several popular computer platforms. Users of the hypertext glossary can navigate quickly in a nonsequential mode by clicking on defined terms within definitions, or by clicking on defined terms in the subject index in Appendix B. Making the Standard available in hypertext on the World Wide Web has significantly advanced the cause of a common, standard vocabulary for telecommunications by extending access to the document to a worldwide audience.

In national fora, ITS leads American National Standards Institute (ANSI)-accredited Technical Committee X3K5 in developing the *American National Standard Dictionary for Information Technology* (ANSDIT). An ITS staff member also serves as project editor for this information terminology standard. During FY 96, a camera-ready revision of this document was delivered to ANSI for publication as American National Standard X3.192.

In the international arena, ITS serves as convener of the joint International Organization for Standardization (ISO)/International Electrotechnical Commission (IEC) Working Group 7, Vocabulary for Data Communications. Working Group 7 met twice during FY 96 to develop vocabulary for databases, e-mail, and network management. An ITS representative also serves as project editor for the English text of several parts of ISO/IEC-2382, *Information Technology—Vocabulary*.

In each committee, ITS works to promote a congruence of definitions so that communication is enhanced for all users of all of the related terminology standards. By actively participating in several such fora, ITS promotes compatibility between Federal Standard 1037C and other vocabulary standards, including ISO/IEC-2382, the ANSDIT, and specialized terminology standards such as the *National Information Systems Security Glossary*. The benefits of common vocabulary in all three are-



Two successive screens visible when navigating through the hypertext version of Federal Standard 1037C, Glossary of Telecommunication Terms.

nas—Federal, national, and international—reach beyond the vocabulary committee and the laboratories to the purchaser's desks, and into the telecommunications marketplace worldwide.

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Wireless Standards Support

Outputs

- Independent observation of the common air-interface technology field trials of the Joint Technical Committee on Wireless Access.
- Conference paper on wireless local area network smart antenna performance improvement.

Wireless technology is on the verge of creating a revolution in communications. Wireless systems and technologies encompass a wide variety of both existing and emerging systems and technologies. These include land mobile radio, HF radio, broadcast radio and television, and multichannel multipoint distribution service; wireless telephone systems such as cellular and personal communications services (PCS) systems; paging; packet radio; wireless local area networks (WLANs); wireless digital modems; and satellite-based systems. New systems and technologies are being developed for both new types of services, such as PCS, and for traditional services, such as broadcast television and radio. With the plethora of new wireless systems and technologies being developed, the need for standards is becoming increasingly important. Without standards for these systems, interoperability of systems is not possible and there is the risk of the user being faced with an overwhelming number of ad hoc, disjointed systems and services. Because of the importance of wireless standards for the development and deployment of future wireless systems and technologies, the Institute is actively involved in supporting standards in areas such as PCS and WLANs.

In the United States, technical standards for the PCS common air interface were developed in the Joint Technical Committee on Wireless Access (JTC). The JTC is a joint activity between Committee T1 of the American National Standards Institute (ANSI) and the Telecommunications Industry Association (TIA). Within the JTC, draft standards for six air-interface technologies for licensed PCS were developed and forwarded to ANSI (see the Table).The JTC field trials for the six air-interface technologies have been completed. The IS-95-based code-division multiple access (CDMA), the IS-136-based time-division multiple access (TDMA), personal access communication system (PACS), and PCS 1900 technologies are currently full standards. The Omnipoint

PCS Technologies and Associated Parameters

Base Technology	Omnipoint (new)	IS-95	PACS (new)	IS-136	GSM	W-CDMA (new)
Access Method	TDMA/ CDMA	CDMA	TDMA	TDMA	TDMA	CDMA
RF Bandwidth	5 MHz	1.25 MHz	300 kHz	30 kHz	200 kHz	5 MHz
Bit Rate (no overhead)	32 kbps	Two Rates Available: 8 kbps or 13.3 kbps	32 kbps	7 kbps	13 kbps	32 kbps
System Type	High and Low Tier	High Tier	Low Tier	High Tier	High Tier	High and Low Tier
Error Control (voice)	None	FEC	None	FEC	FEC	FEC
System Capacity Relative to AMPS	16x	10x	0.8x	3x	2-3x	16x

TDMA/CDMA and the wideband CDMA technologies are currently trial use standards. The TIA is in the process of incorporating the PCS IS-95- and IS-136-based technologies into their respective digital cellular standards. The other four technologies are overseen by Committee T1.

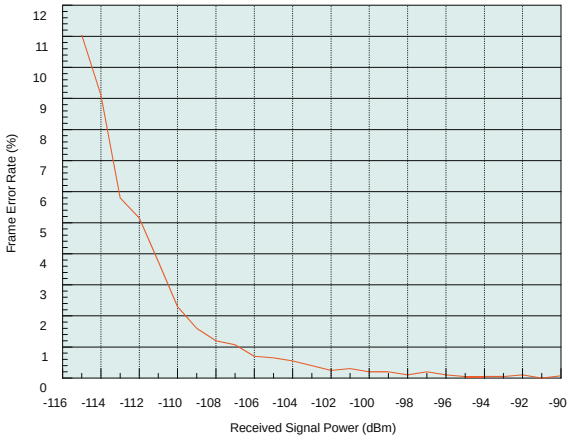
The Institute has supported the PCS standards process by serving as independent observers in all of the JTC PCS technology field trials. In FY 96, to conclude the JTC field testing, the Institute participated as independent observers in both the PACS field trials and the Omnipoint composite TDMA/CDMA field trials. As independent observers, ITS reviewed test procedures, observed the execution of the tests, and directly participated in the data collection, storage, and analysis.

Field testing for all six of the air-interface technologies included measurements of received signal strength, and voice quality and error rate performance as a function of location both with and without interference. Handover testing also was performed. The measurement data were analyzed and the results reported for each technology in a series of six JTC reports. ITS is currently developing a single, concise summary of the field trials that will be published as an NTIA Report. An example of the measurement results, showing frame error rate vs. received signal level for a PCS system during the field trials is given in the Figure.

The demand for WLANs is increasing rapidly as laptop computers and personal digital assistants gain popularity. In addition, WLANs provide a solution to local area network connectivity in applications where cables either cannot be used or are prohibitively expensive. ITS has supported WLAN standards development by its participation in the IEEE 802.11 WLAN standards committee, and its work in radio channel measurements, modeling, and radio system simulation. WLAN devices will operate in the 2.4-GHz industrial, scientific, and medical (ISM) band under the current IEEE 802.11 draft standard. Future WLAN devices will probably move to less congested, higher-frequency bands such as the 5.8-GHz ISM band or the 5-GHz European high performance radio local area network (HIPERLAN) band.

In support of WLAN operation at these higher frequencies, ITS conducted an impulse response measurement study at 5.8 GHz in a warehouse environment. The measurements were made at specific locations throughout the warehouse using an omnidirectional, vertically polarized receive antenna. At each location, 12 impulse response measurements were made using both a horizontally and vertically polarized directional transmit antenna at 6 distinct azimuthal orientations (0, 60, 120, 180, 240, 300 degrees). An additional impulse response measurement was made at each location using an omnidirectional transmit antenna.

Data from these measurements were analyzed to determine WLAN performance improvement using angle-of-arrival discrimination and polarization diversity. The results from this analysis were presented in a paper at the Wireless Communications Conference in Boulder, Colorado in August 1996. These results showed that RMS delay spread (a parameter derived from impulse responses that can be correlated to radio performance) could be reduced using angle-of-arrival discrimination, thus providing improved radio performance. Including polarization diversity with angle-of-arrival discrimination did not substantially reduce the RMS delay spread and therefore would not substantially improve radio performance.



Example frame error rate performance vs. received signal power for a PCS system during the JTC field trials.

Recent Publications

R.J. Achatz, Y. Lo, and E. Pol, "Wireless local area network smart antenna performance improvement," in *Proc. Wireless Communications Conf.*, Boulder, Colorado, 1996, pp. 17-19.

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Standards for Radiocommunication Systems

Outputs

- Federal Telecommunications Standards subcommittee leadership.
- APCO Project 25 task group leadership.
- Federal standards for HF and land mobile radiocommunications.
- Leadership in the Modular Multifunction Information Transfer System Forum.

The National Communications System (NCS) Technology and Standards Division has overall responsibility for managing the Federal Telecommunications Standards Program (FTSP). The FTSP is implemented through an interagency committee structure that comprises the Federal Telecommunications Standards Committee (FTSC) and several related subcommittees. ITS staff members provide leadership and technical contributions in two FTSC subcommittees that develop Federal standards for radiocommunication systems: the High Frequency Radio Subcommittee (HFRS) and the Land Mobile Radio Subcommittee (LMRS). These activities promote technology advancement in the radiocommunications industry and improve the interoperability and effectiveness of radiocommunication systems supporting National Security Emergency Preparedness, and law enforcement needs.

Prior ITS and HFRS efforts have produced a series of Federal standards that specify interface, protocol, and performance requirements for HF automatic link establishment (ALE) radio systems. Commercial radio equipment that implements these standards is becoming widely used in the Federal Government. During FY 96, ITS led the HFRS in preparing three additional Federal standards in this series. The first of these, Federal Standard 1052, specifies technical requirements for high-speed HF modems. This standard was formally approved for publication during FY 96. The other two standards specify baseline ALE radio parameters and requirements for addressing and registration in ALE networks. These standards were completed in draft form and will be coordinated among U.S. Government and industry organizations in FY 97.

To maximize the benefits of standardization, ITS helped promote the development of international standards compatible with the HF ALE standards developed in FTSC. Working with other Federal agencies and the HF Industries Association (HFIA), ITS submitted technical proposals and measurement data supporting ALE standardization to two international standards organizations: the International Telecommunication Union-Radiocommunication Sector Study Group 9C (Fixed Services) and the NATO Communications Standardization Group. Figure 1 summarizes some key linkages between the HFRS and related national and international HF standards organizations.

The Institute also is assisting NCS and the FTSC in developing interoperability standards for digital land mobile radio equipment used in public safety applications. The LMRS is developing advanced land mobile radio (LMR) standards in cooperation with the Association of Public-Safety Communications Officials (APCO) and the National Association of State Telecommunications Directors under APCO Project 25. During FY 96, an Institute representative chaired the APCO Project 25 Encryption Task Group, which develops Project 25 information system security standards. Institute staff members also participated in the Telecommunications Industry Association (TIA) TR 8.3 Encryption Committee and other Project 25 task groups to ensure that their LMR standards meet Federal requirements. Relevant FY 96 outputs included:

- TIA Interim Standard IS102.AAAA, APCO Project 25 DES Encryption Protocol.
- TIA Telecommunications Systems Bulletin TSB102.AAAB, APCO Project 25 Security Services Overview.
- TIA Telecommunications Systems Bulletin TSB102.AACA, APCO Project 25 Over-The-Air-Rekeying (OTAR) Protocol.
- TIA Telecommunications Systems Bulletin TSB102.AACB, Project 25 Over-The-Air-Rekeying (OTAR) Operational Description.
- TIA Interim Standard IS102.AAAC, DES Encryption Conformance.

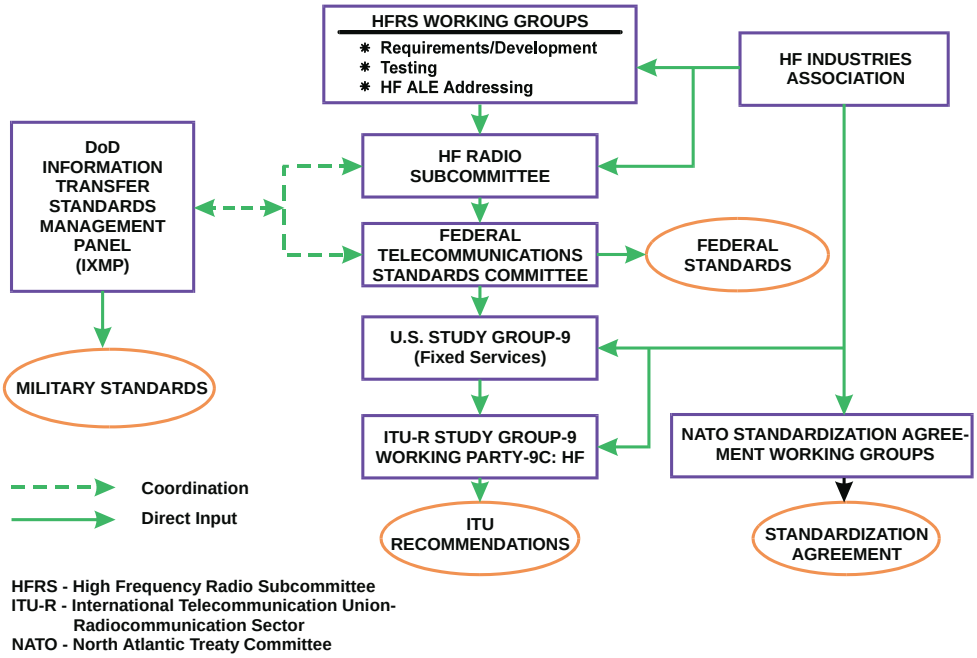

Figure 1. Relationships among U.S. and international HF radio standardization organizations.

- TIA Telecommunications Systems Bulletin, TSB102.AACC, Conformance Test for Project 25 Over-The-Air-Rekeying (OTAR) Protocol.

All of the these documents have been adopted as APCO Project 25 Standards and proposed for adoption as Federal Information-processing Standards.

ITS staff played a strong role in the organization and leadership of a new radio system standardization group, provisionally called the Modular Multifunction Information Transfer System (MMITS) Forum, during FY 96. The Forum's initial membership includes over 100 organizations involved in the development and use of advanced radiocommunication systems and services. Its mission is to specify a modular architecture to facilitate the development of frequency-agile, multiprotocol software-defined radios using advanced digital signal-processing capabilities. The resulting specifications will facilitate interworking among radio systems and services in military, civilian Government, and private sector wireless applications. Figure 2 is the MMITS plan for software-defined radio system development. Institute leadership in MMITS will contribute to realization of this plan.

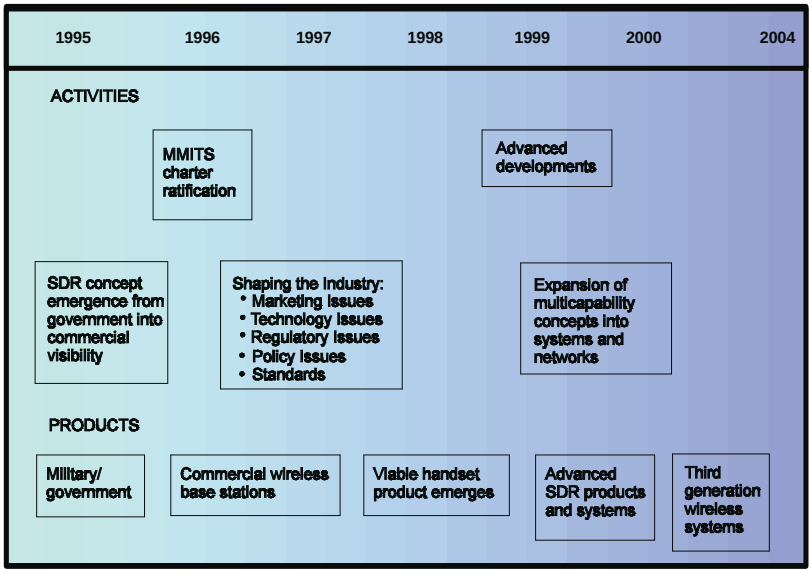

Figure 2. Modular Multifunction Information Transfer System Forum plan for software-defined radio (SDR) system development.

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